

# Response of heart murmur intensity to isometric (handgrip) exercise<sup>1</sup>

D. Bruce McCraw, Wayne Siegel,<sup>2</sup> H. Keith Stonecipher, Donald O. Nutter, Robert C. Schlant, and J. Willis Hurst

From the Division of Cardiology, Department of Medicine, Emory University School of Medicine and Grady Memorial Hospital, Atlanta, Georgia 30303, U.S.A.

*The effects of maximal, voluntary isometric handgrip exercise on the intensity of cardiac murmurs was evaluated in 36 patients and the results compared with the effects of amyl nitrite and phenylephrine. The isometric handgrip exercise produced immediate, reproducible, and significant increases in heart rate and blood pressure. It also increased the intensity of murmurs due to aortic and mitral regurgitation and mitral stenosis and attenuated the murmurs of left ventricular outflow tract obstruction.*

It is not always possible to determine the origin and significance of certain heart murmurs during cardiac auscultation of the resting patient. A variety of physical manoeuvres or pharmacological interventions are available for use in differential diagnosis (Dohan and Criscitiello, 1970).

Isometric handgrip exercise is a form of sustained voluntary muscle contraction shown by Donald *et al.* (1967) rapidly to induce significant increments in heart rate and blood pressure. These circulatory responses are readily obtained in the supine position and are related to the intensity of contraction independent of the muscle mass involved (Lind and McNicol, 1967). A preliminary study from our laboratory (Stonecipher *et al.*, 1970) showed that the haemodynamic changes induced by sustained isometric handgrip produced predictable alterations in the amplitude of murmurs in patients with a variety of cardiac anatomical lesions. We have also reported on the role of isometric stress testing for evoking or accentuating the phonocardiographic and apex cardiographic signs of left ventricular dysfunction (Siegel *et al.*, 1970). Isometric exercise is particularly applicable during auscultation because of the rapid onset and offset of the induced tachycardia and pressor response while the examiner is un-

encumbered by patient movement or the necessity of administering potent pharmacological agents.

The purpose of this study was to document the changes induced by isometric handgrip on the amplitude of heart murmurs in 36 patients with a variety of valvular and other cardiac defects. In over half of these patients the changes in murmur intensity were compared during isometric handgrip and amyl nitrite inhalation or during phenylephrine administration.

## Subjects and methods

Thirty-six patients were studied, of whom 27 had proven cardiac lesions during previous diagnostic cardiac catheterization. The remaining 9 patients were felt to have unquestionable clinical evidence of specific valvular cardiac lesions. The lesions studied are listed in Table 1, and were predominantly aortic and/or mitral defects.

Bipolar praecordial electrocardiograms with the cathode over the sternum at the fourth intercostal space level and the anode at the V<sub>5</sub> position (CM<sub>5</sub>) were recorded simultaneously with phonocardiograms, carotid pulse tracings, and apex cardiograms on an eight-channel Hewlett-Packard photographic recorder<sup>1</sup> at a paper speed of 100 mm/sec. Phonocardiograms were obtained with crystal microphones<sup>2</sup> at the cardiac apex using cut-off frequencies of 50 Hz and 200 Hz; and in the second left intercostal space at 200 Hz with filter slopes of 24 Db/octave. The apex cardiogram and

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<sup>1</sup> Model 4578 Poly Beam Recording System, Hewlett Packard Co., Waltham, Mass.

<sup>2</sup> Model 21050 A, Hewlett Packard Co., Waltham, Mass.

TABLE 1 Response of heart murmur intensity to isometric handgrip exercise, amyl nitrite, and phenylephrine

Cardiac lesion	No. of patients	Isometric handgrip exercise			Amyl nitrite			Phenylephrine		
		Murmur increased	Murmur decreased	Indeterminate or no change	Murmur increased	Murmur decreased	Indeterminate or no change	Murmur increased	Murmur decreased	Indeterminate or no change
Aortic stenosis	4		3	1	2				1	1
Aortic regurgitation	12	9		3		5	4	5		3
Mitral stenosis	10	9		1	4		3		2	3
Mitral regurgitation	14	11		3	4	5	3	8		2
Pulmonary stenosis	3	2		1	2					2
Ventricular septal defect	3	2		1		1	2			2
Idiopathic hypertrophic subaortic stenosis	1		1		1					
Membranous subaortic stenosis	1			1			1			1

carotid pulse tracings were obtained using inductance displacement transducers<sup>1</sup> (time constant = ∞). AC amplifiers with 4-second time constants<sup>2</sup> were used for signal conditioning. Recordings were performed at rest, during the last 15 seconds of isometric exercise, and during administration of amyl nitrite and phenylephrine as described below.

**Isometric handgrip exercise testing** Each patient was positioned in the supine or left lateral decubitus position for all recordings. After resting recordings were obtained, a sustained maximal effort handgrip was maintained for one minute using a handgrip dynamometer. The strength of the handgrip during the last 15 seconds during which recordings were made was approximately 75 per cent of the instantaneous peak maximal

handgrip strength. Blood pressure was measured in the non-exercising arm during rest and exercise using a standard blood pressure cuff (113 cm × 13.5 cm). All patients were instructed to breathe normally to avoid performing the Valsalva manoeuvre. Fig. 1 illustrates the dynamometer and isometric handgrip exercise technique. All 36 patients performed isometric handgrip exercise; of these, 27 also received amyl nitrite and, of these, 19 also received phenylephrine. One patient of the 36 received phenylephrine after isometric handgrip exercise without previous amyl nitrite inhalation. Amyl nitrite and phenylephrine were administered to compare the effect upon the murmurs of the tachycardia induced by amyl nitrite with that induced by isometric handgrip, and to compare the effects of the pressor response induced by phenylephrine with that of isometric handgrip. Amyl nitrite inhalation was begun after control tracings were obtained and after a sufficient period was allowed for the patient to return to the resting state (2 to 5 minutes).

<sup>1</sup> APT-16, Hewlett Packard Co., Waltham, Mass.

<sup>2</sup> 350 Series, High Gain Amplifier, Hewlett Packard Co., Waltham, Mass.

TABLE 2 Mean heart rate and blood pressure responses to isometric handgrip exercise, amyl nitrite, and phenylephrine

Cardiac lesion	No. of patients	Variable	Control	Isometric handgrip exercise	Amyl nitrite	Phenylephrine
Aortic stenosis	4	Heart rate	82	93	106	60
		Blood pressure	113/75	154/98		135/88
Aortic regurgitation	12	Heart rate	74	88*	104	67*
		Blood pressure	129/65	162*/84*		161*/74*
Mitral stenosis	10	Heart rate	74	85*	111*	57*
		Blood pressure	119/78	146*/96*		151†/92†
Mitral regurgitation	14	Heart rate	71	85*	109*	62*
		Blood pressure	123/70	147*/88*		145*/81*
Pulmonary stenosis	3	Heart rate	77	78	115	73
		Blood pressure	147/92	170/107		140/100
Ventricular septal defect	3	Heart rate	78	81	99	57
		Blood pressure	115/80	130/93		135/95

Blood pressure and heart rate measurements were performed immediately before recording phonocardiograms and pulse tracings during isometric handgrip exercise, amyl nitrite, and phenylephrine.

\*  $P < 0.01$ .

†  $P < 0.02$ .

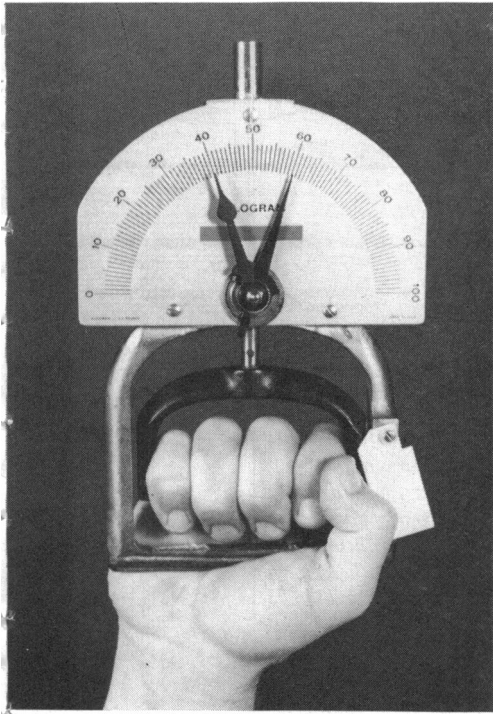


FIG. 1 The spring loaded handgrip dynamometer calibrated in kilogrammes.

When a reflex tachycardia was induced, inhalation was stopped and tracings were recorded. After again allowing sufficient time for the patient to return to the resting state (5 to 10 minutes) a standard dose of 0.25 mg phenylephrine was slowly administered intravenously. If the blood pressure response exceeded that of handgrip, recordings were purposely delayed until the pressor response (with its associated reflex bradycardia) approximated that induced by handgrip. If the blood pressure did not exceed that induced by handgrip, the dose was not repeated.

## Results

Table 1 lists the changes in murmur intensity to isometric handgrip exercise and drugs; the total of the number of patients listed for each lesion equals more than the actual number of patients tested since many patients had more than one murmur. Table 2 lists the mean heart rate and blood pressure responses to isometric handgrip exercise and drugs.

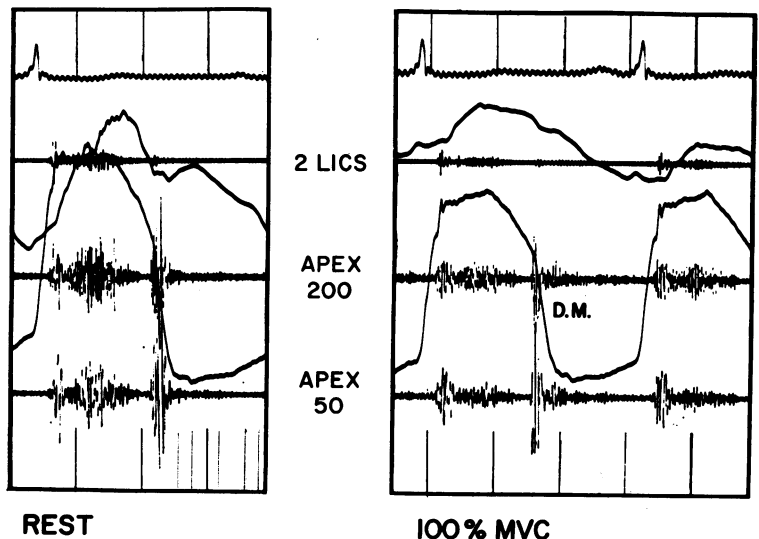
**Aortic stenosis** Isometric handgrip exercise decreased the murmur of aortic stenosis in 3 of 4 patients with no significant change in 1 patient. Amyl nitrite increased the murmur in both patients tested. Phenylephrine de-

creased the murmur in 1 patient and produced no significant change in another.

**Aortic regurgitation** Isometric handgrip exercise increased the murmur of aortic regurgitation in 9 of 12 patients with no significant change in 3 patients. Amyl nitrite decreased the murmur in 5 of 9 patients tested with no significant change in 4 patients. Phenylephrine increased the murmur in 5 of 8 patients tested with no significant change in 3 patients. The effect of isometric handgrip exercise on the murmurs of aortic stenosis and regurgitation is graphically illustrated in Fig. 2 and 3.

**Mitral stenosis** Isometric handgrip exercise increased the murmur of mitral stenosis in 9 of 10 patients with no significant change in one patient. Amyl nitrite increased the murmur in 4 of 7 patients tested with no significant change in 3 patients. Phenylephrine decreased the murmur in 2 of 5 patients tested with no significant change in 3 patients.

FIG. 2 Graphic recordings at rest and during a maximal voluntary handgrip contraction (100% MVC) from a woman with moderate valvular aortic stenosis and regurgitation. Handgrip increased the heart rate from 83 to 93 beats/minute and the blood pressure from 120/90 to 170/100 mmHg. The systolic murmur of aortic stenosis decreases and the diastolic murmur of aortic regurgitation is accentuated during 100 per cent MVC.



**Mitral regurgitation** Isometric handgrip exercise increased the murmur of mitral regurgitation in 11 of 14 patients with no significant change in 3 patients. Amyl nitrite increased the murmur in 4 of 12 patients tested, decreased the murmur in 5 patients, and gave no significant change in 3 patients. Phenylephrine increased the murmur in 8 of 10 patients tested with no significant change in 2 patients. The graphic recordings from patients with mitral stenosis and mitral regurgitation obtained before and during isometric handgrip exercise are shown in Fig. 4 and 5.

**Pulmonary stenosis** Isometric handgrip exercise increased the murmur of valvular pulmonary stenosis in 2 of 3 patients with no significant change in one patient. Amyl nitrite increased the murmur in both patients tested and phenylephrine produced no significant change in both patients tested.

**Ventricular septal defect** Three patients, two with congenital defects and one with a traumatic defect, were studied. None of these defects was associated with pulmonary hypertension. Isometric handgrip exercise increased the murmur in 2 of 3 patients and produced no significant change in 1 patient. Amyl nitrite decreased the murmur in 1 of 3 patients with no significant change in 2 patients. Phenylephrine produced no significant change in either of two patients tested.

**Idiopathic hypertrophic subaortic stenosis (hypertrophic obstructive cardiomyopathy)** Isometric handgrip exercise decreased the murmur and amyl nitrite increased the murmur in the one patient studied. A similar response in association with a decrease in the left ventricular outflow obstruction was observed in two additional patients studied during cardiac catheterization.

**Membranous subaortic stenosis** In one patient all three procedures produced no change.

## Discussion

The results of this study indicate that the blood pressure and heart rate increase occurring during isometric handgrip exercise significantly affect the intensity of certain types of heart murmurs.

Isometric exercise in normal subjects results in a potent cardiovascular reflex characterized by tachycardia, an increase in cardiac

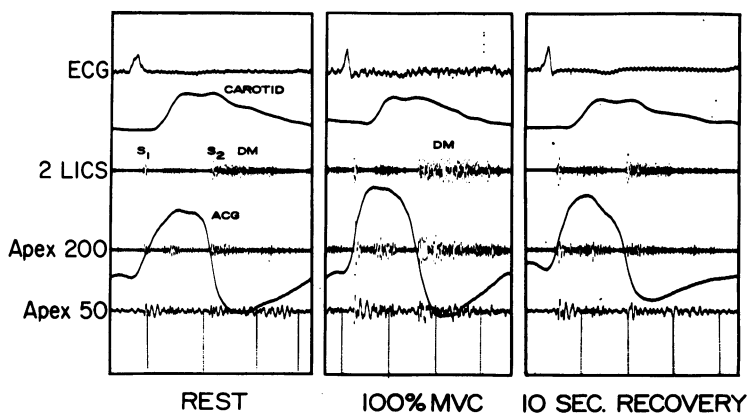


FIG. 3 Graphic recordings (from left to right) at rest, during a maximal voluntary handgrip contraction (100% MVC), and 10 seconds after release of 100 per cent MVC from a patient with moderately severe aortic regurgitation. The 100 per cent MVC increased the heart rate from 65 to 80 beats/minute and the blood pressure from 120/48 to 152/55 mmHg. Note the obvious accentuation of the aortic diastolic murmur during 100 per cent MVC and the rapid return to normal intensity after handgrip release.

output, and an increase in both systolic and diastolic pressure. Freyschuss (1970) has shown the tachycardia to be mediated by the release of vagal tone and the pressor response to result from both the increase in heart rate and cardiac output and an increase in systemic vascular resistance mediated by the sympathetic nervous system. We have demonstrated similar reflex increases in heart rate, cardiac output, and systemic and pulmonary arterial pressure during isometric handgrip exercise performed during cardiac catheterization in over 60 patients with a variety of acquired and congenital cardiovascular lesions (manuscript in preparation).

The basic pharmacological action of amyl nitrite is to relax smooth muscle. Amyl nitrite causes a decrease in systemic vascular resistance and systemic arterial pressure accompanied by a reflex increase in heart rate and probable venoconstriction with an increased venous return (Beck *et al.*, 1961). The cardiac output and ejection velocity are increased whereas little change occurs in stroke volume (Perloff *et al.*, 1963).

Phenylephrine is a potent pressor agent acting through vascular sympathetic alpha receptors to produce an obvious increase in systemic vascular resistance (Innes and Nickerson, 1970). The pressor response to

phenylephrine is accompanied by reflex bradycardia, little change in stroke volume, and a resultant decrease in cardiac output (Beck *et al.*, 1961).

The increased intensity of aortic and mitral regurgitant murmurs with isometric handgrip exercise can be explained by the significant elevation of aortic diastolic and left ventricular systolic pressures that accompanies isometric exercise. Phenylephrine also increased aortic and left ventricular pressure and increased the intensity of aortic and mitral regurgitation murmurs in our patients as previously noted by Luisada and Madoery (1966). The observation in our patients that amyl nitrite either decreases or does not alter the murmur of aortic regurgitation while exerting a variable effect, including a 'paradoxical' increase, on the murmur of mitral regurgitation is in accord with Luisada and Madoery (1966).

Although only 4 patients with valvular aortic stenosis were studied, isometric handgrip decreased the systolic murmur in 3 patients. This effect may result from the decrease in systolic gradient that has been described when systemic resistance is raised (Perloff *et al.*, 1967; Silove, Vogel, and Grover, 1968), and during dynamic exercise (Anderson *et al.*, 1969). The murmur response, in 2 patients with aortic stenosis, to amyl nitrite and phenylephrine was expected, based on the haemodynamic action of these agents.

The diastolic rumble of mitral stenosis increased in intensity during isometric handgrip exercise. The shorter diastolic filling period associated with tachycardia during isometric handgrip may explain the increase in murmur intensity. A similar increase in the mitral rumble with dynamic exercise can be explained by an increase in mitral valve flow rate that results during tachycardia and an increase in cardiac output (Kasalický *et al.*, 1968). Amyl nitrite is also thought to augment the rumble of mitral stenosis by causing tachycardia and an increase in cardiac output (Tavel, 1967). The failure of amyl nitrite to increase the mitral rumble in 3 of 7 patients tested in this study is unexplained. Though phenylephrine might be expected to decrease the rumble of mitral stenosis, by increasing diastolic filling time and reducing cardiac output, this was observed in only 2 of 5 patients tested.

The problems and danger of isometric exercise testing deserve comment. Patient co-operation, in order to achieve maximal voluntary contractions, is more important than during pharmacological intervention, and care must be taken to avoid a Valsalva manoeuvre

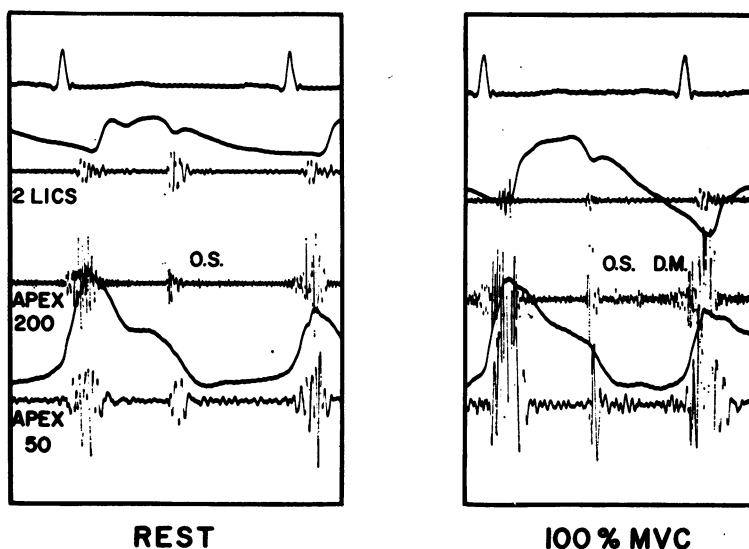
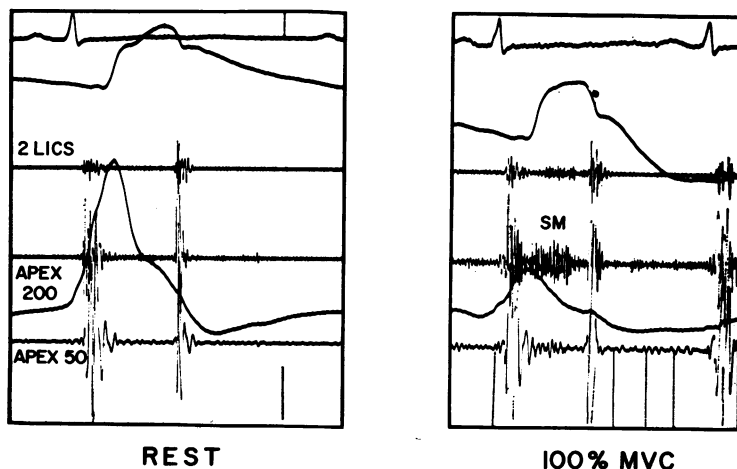


FIG. 4 Graphic recordings from a young woman with mild mitral stenosis (mitral valve area =  $2.1 \text{ cm}^2$ ). Maximal handgrip exercise (100% MVC) increased the heart rate from 86 to 100 beats/minute and increased the intensity of the mitral diastolic murmur (DM). OS = opening snap.

FIG. 5 Graphic recordings from a patient with mild mitral regurgitation illustrating the obvious accentuation of the systolic murmur during maximal handgrip exercise (100% MVC).



during the test. Matthews *et al.* (1971) have reported dangerous dysrhythmias in patients with cardiac disease during performance of isometric handgrip exercise. Though we have precipitated ventricular ectopic rhythms in only 3 subjects, all of which reverted spontaneously, during approximately 200 tests in a variety of cardiac patients, it is recommended that electrocardiographic monitoring be used during isometric exercise in patients with left ventricular dysfunction or rhythm disorders. Obvious arterial hypertension, recent myocardial infarction, and cerebrovascular disease, including vascular malformations, are contraindications to the use of sustained isometric exercise of any muscle group.

In conclusion, isometric exercise produces haemodynamic alterations that include the major characteristics of both amyl nitrite and phenylephrine administration, i.e. tachycardia and a significant increase of systemic arterial pressure. Isometric handgrip exercise has proved to be a simple, noninvasive bedside manoeuvre for amplifying the murmurs of aortic and mitral regurgitation and mitral stenosis. This manoeuvre attenuates murmurs originating from outflow tract obstruction of the left ventricle.

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Requests for reprints to Dr. Donald O. Nutter, School of Medicine, Woodruff Medical Center of Emory University, Thomas K. Glenn Memorial Building, 69 Butler Street, S.E., Atlanta, Georgia 30303, U.S.A.